Novel protocol for knee mobilization under femoral and sciatic nerve blocks for postoperative knee stiffness

Wanivenhaus, Florian ; Tscholl, Philippe M ; Aguirre, Jose ; Giger, René ; Fucentese, Sandro F

Abstract: The purpose of this study was to evaluate the effectiveness of intermittent femoral and sciatic nerve blocks combined with an in-house physiotherapy protocol for treating postoperative knee stiffness. Sixty-eight patients with postoperative knee stiffness were evaluated for passive knee flexion and extension at different time points, beginning preoperatively and continuing throughout a median 10-month follow-up after mobilization intervention. Sciatic and femoral nerve catheters were activated 1 hour prior to each physiotherapy session, which was performed twice per day and supported by a continuous passive range of motion machine. Median time from admission to catheter removal was 4 days (range, 1-8 days). Mean hospital length of stay was 7 days (range, 2-19 days). Overall mean flexion increased significantly from pretreatment (74°) to discharge (109°; $P<.01$). There was no significant difference in mean flexion at 6-week follow-up compared with that at discharge (108°; $P=.764$), but there was a significant increase in flexion at final follow-up (120°; $P=.002$). Overall mean knee extension lag decreased significantly from pretreatment (5°) to discharge (0.4°; $P=.001$). There was no significant increase in mean extension lag from discharge to final follow-up (1°; $P=.2$). Overall, 11 patients underwent revision surgery for persistent stiffness. This novel protocol for continuous knee mobilization under perineural blocks is a valuable alternative to knee manipulation under anesthesia for this select group of procedures. The 2 techniques produced a similar early range of motion gain, but the reported protocol resulted in less range of motion loss at follow-up and fewer possible complications.

DOI: https://doi.org/10.3928/01477447-20160419-07

Originally published at:
Wanivenhaus, Florian; Tscholl, Philippe M; Aguirre, Jose; Giger, René; Fucentese, Sandro F (2016). Novel protocol for knee mobilization under femoral and sciatic nerve blocks for postoperative knee stiffness. Healio Orthopedics, 39(4):e708-e714.
DOI: https://doi.org/10.3928/01477447-20160419-07

Novel Protocol for Knee Mobilization Under Femoral and Sciatic Nerve Blocks for Postoperative Knee Stiffness

Florian Wanivenhaus, MD; Philippe M. Tscholl, MD; José A. Aguirre, MD, MSc;
René Giger, PT, MAS; Sandro F. Fucentese, MD

abstract

The purpose of this study was to evaluate the effectiveness of intermittent femoral and sciatic nerve blocks combined with an in-house physiotherapy protocol for treating postoperative knee stiffness. Sixty-eight patients with postoperative knee stiffness were evaluated for passive knee flexion and extension at different time points, beginning preoperatively and continuing throughout a median 10-month follow-up after mobilization intervention. Sciatic and femoral nerve catheters were activated 1 hour prior to each physiotherapy session, which was performed twice per day and supported by a continuous passive range of motion machine. Median time from admission to catheter removal was 4 days (range, 1-8 days). Mean hospital length of stay was 7 days (range, 2-19 days). Overall mean flexion increased significantly from pretreatment (74°) to discharge (109°; *P*<.01). There was no significant difference in mean flexion at 6-week follow-up compared with that at discharge (108°; *P*=.764), but there was a significant increase in flexion at final follow-up (120°; *P*=.002). Overall mean knee extension lag decreased significantly from pretreatment (5°) to discharge (0.4°; *P*=.001). There was no significant increase in mean extension lag from discharge to final follow-up (1°; *P*=.2). Overall, 11 patients underwent revision surgery for persistent stiffness. This novel protocol for continuous knee mobilization under perineural blocks is a valuable alternative to knee manipulation under anesthesia for this select group of procedures. The 2 techniques produced a similar early range of motion gain, but the reported protocol resulted in less range of motion loss at follow-up and fewer possible complications. [*Orthopedics.*]

Arthrofibrosis of the knee is a complication of total knee arthroplasty (TKA) and knee ligament surgery, leading to frustration for both patient and surgeon.[1] Arthrofibrosis is defined as abnormal scarring of the joint, wherein the formation of dense fibrous tissue prevents full range of motion (ROM).[1] According to the current literature, the incidence of knee stiffness after TKA ranges between 1.8% and 23.0%, depending on the definition of stiffness.[2-4] Small flexion deficits typically do not alter gait, although most people notice unilateral loss of flexion.[5] Extension deficit is generally more disabling than flexion loss because even minimal deficits place undue strain on the quadriceps muscle and patellofemoral joint.[5] Various treatment modalities for stiffness have been described, including mobilization under anesthesia (MUA),[4,6] low-stretch devices,[7] and arthroscopic[1] or open arthrolysis. However, several complications from MUA have been reported, including fractures, wound dehiscence, patellar ligament avulsion, hemarthrosis,

The authors are from the Department of Orthopaedics (FW, PMT, SFF), the Division of Anesthesiology (JAA), and the Division of Physiotherapy (RG), Balgrist University Hospital, University of Zurich, Zurich, Switzerland.

The authors have no relevant financial relationships to disclose.

The authors thank Prof Dr Burkhardt Seifert for statistical support.

Correspondence should be addressed to: Florian Wanivenhaus, MD, Department of Orthopaedics, Balgrist University Hospital, University of Zurich, 340 Forchstrasse, Zurich 8008, Switzerland (florian@wanivenhaus.at).

Received: December 23, 2015; Accepted: March 8, 2016.

doi: 10.3928/01477447-20160419-07

heterotopic bone formation, and pulmonary embolism.[8-11]

In the current retrospective study, patients who were scheduled for elective TKA, ligament reconstruction, or a patellofemoral stabilizing procedure leading to insufficient postoperative ROM were treated according to a novel protocol for knee mobilization under intermittent femoral and sciatic nerve blocks and a standardized in-house physiotherapy program.

Treating pain after invasive surgical procedures using continuous perineural catheters in the immediate postoperative period has been reported previously for the in-hospital[12] and at-home settings.[13] However, their application in nonoperative patients and their longer-term, post-infusion effects on ROM remain uninvestigated for the lower extremity.[14]

The current authors' objectives were to (1) evaluate the effectiveness of mobilizing the knee under intermittent perineural blocks and in-house physiotherapy to improve knee flexion and extension, (2) compare the results of patients with post-TKA stiffness with the results of patients who underwent arthroscopic or other open knee operations, and (3) determine whether the gained flexion and extension diminished over time.

Materials and Methods

The Cantonal Ethical Committee approved this retrospective study (#2014-0633). Written informed consent was obtained from each participant.

All patients who required treatment for knee stiffness after knee surgery between January 2008 and July 2013 were included. The inclusion criterion was the presence of knee stiffness after TKA, arthroscopic surgery, or surgery for patellofemoral instability. Knee stiffness was defined as flexion of less than 90° and an extension deficit that negatively affected daily knee joint function. Inclusion in the treatment protocol was based on the lack of progress in knee flexion or extension loss under outpatient physiotherapy. Exclusion criteria included all causes of knee stiffness attributed to technical factors, such as component malpositioning or sizing errors in TKA patients, graft malplacement in ligament reconstruction cases, or complications such as infection or fracture.

Passive flexion, extension, and total ROM were evaluated in all patients with a standard goniometer preoperatively [time of surgery ($T_{surgery}$)], at the start of the in-house physiotherapy protocol ($T_{admission}$) (before activation of the femoral and sciatic nerve blocks), at the time of the last activation of the catheters ($T_{catheter}$), on the day of discharge from the hospital after mobilization ($T_{discharge}$), at 6-week follow-up (FU) ($T_{6weekFU}$), and at final follow-up (T_{lastFU}).

For comparative analysis, patients were divided into 3 groups: (1) those with TKA; (2) those with arthroscopy or arthroscopically assisted ligament reconstruction; and (3) those with surgery for patellofemoral instability (medial patellofemoral ligament [MPFL] reconstruction, trochleoplasty, tibial tubercle osteotomy). Two subgroup analyses compared (1) patients undergoing TKA vs others not undergoing TKA and (2) patients who underwent arthroscopic surgery vs those who underwent surgery for patellofemoral disorders.

Perineural Catheter Protocol

The puncture site for the femoral nerve catheter was located 5 cm below a line joining the anterosuperior iliac spine and the pubic tubercle and 1 to 2 cm lateral to the femoral artery. Femoral nerve block was performed after disinfection and local anesthesia of the skin with 2 mL of lidocaine 1%. The catheter was placed under sterile conditions facilitated by a nerve stimulator technique, wherein a 30° short, beveled, 21-gauge needle (Stimuplex A; Braun Melsungen AG, Melsungen, Germany) was connected to a nerve stimulator (Stimuplex HNS 11; Braun Melsungen AG) with the following initial settings: 1.4 mA current intensity, 0.1 ms impulse duration, 2 Hz frequency. The needle was cranially directed 45° to the skin. After a "dancing patella" response was obtained between 0.3 and 0.4 mA, a 20-gauge catheter with 3 lateral holes (Polymedic; Te Me Na, Bondi, France) was placed using the cannula-over-needle technique. The catheter was secured by subcutaneous tunneling through an 18-gauge intravenous catheter and fixed to the skin with transparent adhesive tape.

The proximal lateral sciatic nerve block on the thigh was performed according to Guardini et al.[15] The puncture point was 2 cm distal to the greater trochanter, and a needle connected to a nerve stimulator (with initial settings previously described) was introduced. Needle placement was successful when plantar flexion of the foot could be elicited with current intensity between 0.3 and 0.4 mA. The catheter was then placed and secured (**Figure 1A**). The catheters were assessed twice daily for signs of infection or dislocation.

Physiotherapy Protocol

Physiotherapy started after successful catheter placement and injection of 20 and 30 mL of ropivacaine 0.5% through the femoral and the sciatic nerve catheter, respectively. Catheter activation was performed 1 hour prior to each physiotherapy session, which was performed twice daily. The physiotherapy session focused on passive mobilization of the knee joint in supine, prone, and sitting positions with the aim of small gains of ROM during every therapy session (**Figures 1B-D**). The sessions were supported by a continuous passive ROM bedside machine (3 times per day for 1 hour each time) (**Figure 1E**). When a satisfactory ROM plateau was reached, typically after 3 to 4 days, physiotherapy continued under oral analgesics, including nonsteroidal anti-inflammatory drugs, referring to the pain treatment of the World Health Organization (WHO), without activation of the perineural catheters. Once ROM was preserved under oral analgesics, discharge could occur. A detailed outpatient physiotherapy plan was developed to preserve the gained ROM, with the focus on active exercises (coordination skills, automated motion patterns, strength training).

Figure 1: Femoral and sciatic nerve blocks in place (a). Passive mobilization of the knee by a physiotherapist at the end of the knee mobility exercise (b-d). Mobilization is supported by a continuous passive range of motion bedside machine (e).

Table 1

Standardized Knee Surgeries

Surgery	No. of Patients (Knees)	Patient Group
Knee arthroplasty	35 (36)	Total knee arthroplasty
ACL reconstruction	8 (8)	Arthroscopy
PCL reconstruction	2 (2)	Arthroscopy
Combined 1-stage ACL and PCL reconstruction	6 (6)	Arthroscopy
Arthroscopic meniscus repair	2 (2)	Arthroscopy
Knee arthroscopy	4 (4)	Arthroscopy
Trochleoplasty	4 (4)	Patellofemoral
MPFL reconstruction	6 (7)	Patellofemoral
Tibial tubercle osteotomy	1 (1)	Patellofemoral

Abbreviations: ACL, anterior cruciate ligament; MPFL, medial patellofemoral ligament; PCL, posterior cruciate ligament.

Statistical Analysis

Statistical analysis was performed with IBM SPSS Statistics version 20.0 software (IBM Corp, Armonk, New York). The Wilcoxon signed rank test was used to assess comparisons at different time points and among groups. Statistical significance was defined as a *P* value less than .01.

Results

During the study period, 68 patients (42 women and 26 men; median age, 49 years [range, 18-82 years]) met the inclusion criteria. Median body mass index was 26.1 kg/m^2 (range, 18.3-36.6 kg/m^2). Two patients underwent 2-stage bilateral treatment. For comparative analysis, the patients were divided into 3 groups determined by the surgical interventions they underwent (**Table 1**).

Mean time from surgery to admission for the in-house physiotherapy program under femoral and sciatic nerve blocks was 96±70 days. Median time from admission for mobilization to discontinuing catheter activation ($T_{admission}$ to $T_{catheter}$) was 4 days (range, 1-8 days). Median hospital length of stay ($T_{admission}$ to $T_{discharge}$) was 7 days (range, 2-19 days). Median final follow-up assessment occurred at 10 months (range, 1-57 months).

Mean overall passive knee flexion increased significantly between admission and catheter discontinuation ($T_{admission}$, 74.2°±22.9°; $T_{catheter}$, 120.2°±11.4°; P=.001). There was a significant mean decrease in flexion from the end of catheter treatment to hospital discharge ($T_{discharge}$, 108.9°±18.2°; P=.001). There was no significant difference in mean knee flexion at 6-week follow-up compared with that at discharge ($T_{6weekFU}$, 108.4°±20.9; P=.764). However, there was a significant increase in mean flexion at final follow-up assessment (T_{lastFU}, 119.6°±18.9°; P=.002) (**Figure 2**).

Mean overall passive knee extension lag decreased significantly between admission and catheter discontinuation ($T_{admission}$, 5.4°±7.5°; $T_{catheter}$, 0.3°±3.1°; P=.001). There was no significant difference in mean extension lag from the end of catheter treatment to the end of the hospital stay during the mobilization program ($T_{discharge}$, 0.4°±3°; P=.26). There was a significant increase in mean knee extension lag at $T_{6weekFU}$ compared with mean extension lag at $T_{discharge}$ ($T_{6weekFU}$, 2.1°±4.2°; P=.005), but there was no significant difference at final follow-up assessment (T_{lastFU}, 1.1°±3.3°; P=.2) (**Figure 3**).

The results for the subgroup analysis comparing TKA with other types of knee surgeries and those for the arthroscopy group vs patients who underwent surgery for patellofemoral instability are shown in **Table 2**. There was significantly decreased mean passive knee flexion at the time of catheter discontinuation between patients undergoing TKA and the control

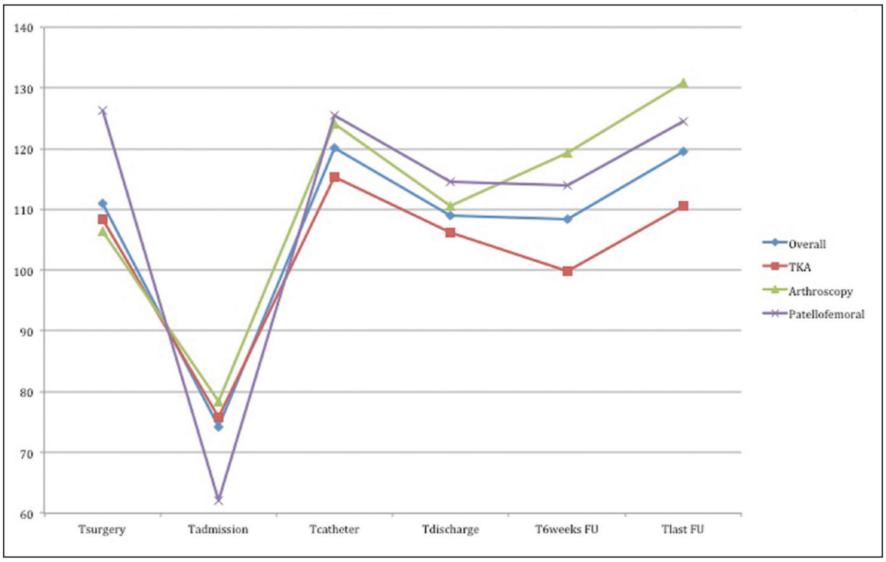

Figure 2: Passive knee flexion at various time (T) points during follow-up (FU) for all patients (Overall); those with total knee arthroplasty (TKA); patients with arthroscopy or arthroscopically assisted ligament reconstruction (Arthroscopy); and patients who underwent trochleoplasty, medial patellofemoral ligament reconstruction, or tibial tubercle osteotomy (Patellofemoral).

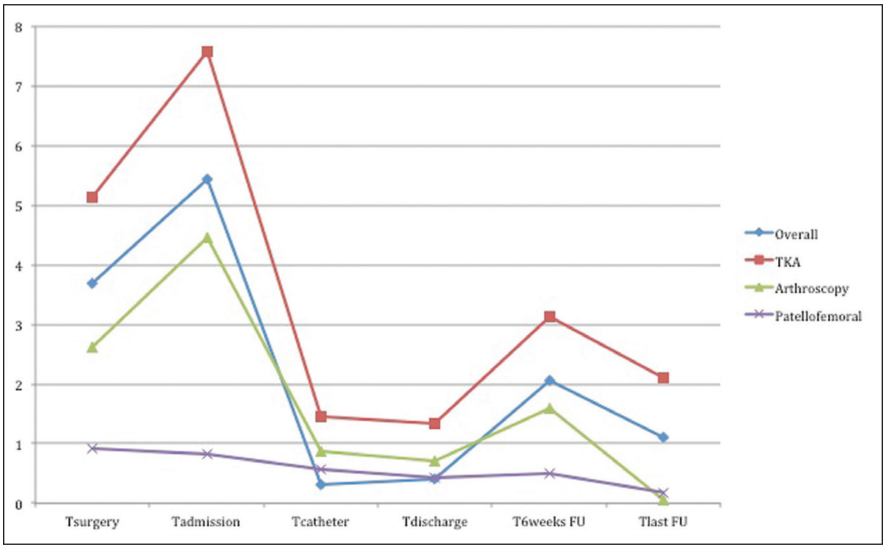

Figure 3: Passive knee extension lag at various time (T) points during follow-up (FU) for all patients (Overall); those with total knee arthroplasty (TKA); patients with arthroscopy or arthroscopically assisted ligament reconstruction (Arthroscopy); and patients who underwent trochleoplasty, medial patellofemoral ligament reconstruction, or tibial tubercle osteotomy (Patellofemoral).

group (P=.006). A significantly increased mean knee extension lag was seen at discharge in the TKA group (P=.008). Moreover, there was significantly decreased mean knee flexion at 6 weeks and at final follow-up in the TKA group (P=.001). There were no significant differences in ROM at any of the postmobilization time points between the arthroscopy group and the patellofemoral group.

One fall was observed, which was caused by weakness due to an insensate lower extremity after perineural catheter activation, although patients were routinely fitted with an extension knee brace during the intermittent catheter activation period. Catheter replacement was needed twice in the same patient for incomplete block. The catheters were removed from 1 patient after 6 days because of perifocal soft tissue inflammation. Additional MUA was performed in 9 patients because of no ROM improvement during the first 2 days of mobilization under perineural blocks. Treatment of the extension lag was supported in 4 other patients by a custom-made, low-stretch splint. Eleven patients underwent revision surgery for knee stiffness after final follow-up.

In 2 cases, revision TKA was performed due to remaining stiffness and pain. In 1 case, a secondary patella resurfacing after TKA was performed due to persistent pain and stiffness. In addition, a patellofemoral prosthesis was implanted in 1 case due to persistent pain, stiffness, and patellofemoral arthrosis after an initial tibial tubercle osteotomy. Moreover, a 2-staged revision TKA was performed in 1 case due to a periprosthetic joint infection, which was diagnosed after an initially negative joint aspirate. A revision MPFL reconstruction was performed due to persistent stiffness and pain in 3 cases. Finally, a revision arthroscopy for hardware removal and debridement was performed in 2 cases.

Discussion

The main finding of this study was that mobilization of stiff knees under intermittent femoral and sciatic nerve blocks followed by physiotherapy is a feasible method for improving passive knee flexion and extension. The improved knee flexion was preserved at least until the final follow-up assessment at a median of 10 months. Mean extension lag was significantly decreased by this treatment and was maintained until final follow-up. Immediately after perineural catheter removal, knee flexion significantly decreased temporarily, returning to the gained ROM at final follow-up.

Table 2

Subgroup Analysis for Patients Undergoing TKA and Patients Undergoing Arthroscopy or Arthroscopically Assisted Ligament Reconstruction

	TKA vs Control[a]			Arthroscopy vs Control[b]		
Variable	**TKA**	**Control**	***P***	**Arthroscopy**	**Control**	***P***
Cases, No.	36	34		22	12	
Age, mean (range), y	60 (37-82)	33 (18-50)	.001	35 (18-50)	29 (18-49)	.19
$T_{surgery}$ to $T_{admission}$, mean±SD, d	108±90.7	83±33.7	.24	84±36.8	80.5±28.6	.94
$T_{admission}$ to $T_{discharge}$, mean±SD, d	7.3±2.5	6.7±3.2	.21	7.3±3.7	5.8±1.8	.18
ROM at $T_{surgery}$, mean±SD						
Flexion	108°±26°	114°±35°	.09	106°±39°	126°±24°	.27
Extension lag	5°±6°	2°±5°	.04	3°±5°	1°±4°	.44
ROM at $T_{admission}$, mean±SD						
Flexion	75°±22°	73°±24°	.75	78°±22°	62°±24°	.54
Extension lag	8°±8.174°	3°±6°	.01	4°±7°	1°±4°	.12
ROM at $T_{catheter}$, mean±SD						
Flexion	115°±7°	125°±13°	.006	124°±12°	126°±14°	.75
Extension lag	1°±3°	1°±3°	.01	1°±3°	1°±2°	.91
ROM at $T_{discharge}$, mean±SD						
Flexion	106°±14°	112°±22°	.11	110°±23°	115°±20°	.69
Extension lag	1°±3°	1°±2°	.008	1°±3°	0°±1°	.93
ROM at $T_{6weekFU}$, mean±SD						
Flexion	100°±14°	118°±23°	.001	119°±22°	114°±27°	.60
Extension lag	3°±5°	1°±3°	.33	2°±4°	1°±2°	.14
ROM at $T_{last\ FU}$, mean±SD						
Flexion	110°±19°	129°±14°	.001	131°±13°	125°±17°	.47
Extension lag	2°±4°	0°±1°	.03	0°±2°	0°±2°	.96

Abbreviations: FU, follow-up; ROM, range of motion; T, time; TKA, total knee arthroplasty.
[a]*Patients who did not undergo total knee arthroplasty.*
[b]*Patients who underwent surgery for patellofemoral disorders.*

Despite the use of continuous femoral and sciatic nerve block being controversial for postoperative pain treatment,[16] they are currently used in different regimens for postoperative analgesia.[17] Because the use of perineural catheters for the upper extremity has successfully been described for the ambulant treatment of adhesive capsulitis manipulation,[14] and due to the low success rate of other treatments, a perineural catheter–based approach for mobilization seemed a logical consequence.

Several techniques have been used in patients with knee arthrofibrosis for whom outpatient physiotherapy has failed, including MUA, low-stretch devices, and open or arthroscopic debridement. Two large series analyzing the outcome after TKA reported a prevalence of 1.3%[18] and 5.3%.[19] The incidence of loss of motion after anterior cruciate ligament (ACL) reconstruction has been reported to vary between 2% and 6% but may rise to 30% to 57% in patients with combined ACL and posterior cruciate ligament reconstructions for knee dislocation.[20-23] Manipulation under anesthesia is recommended by many authors as a first-line treatment for knee stiffness following TKA in patients for whom physical therapy fails and whose motion deficits are not attributed to surgical error.[24] Most authors recommend MUA as an early treatment for stiffness after TKA, starting as early as 6 to 12 weeks following the initial surgery.[19] The mobilization intervention in the current study was performed at a mean of 96 days postoperatively.

Several complications are associated with MUA, including fractures, wound dehiscence, patellar ligament avulsion, hemarthrosis, heterotopic bone formation, initiation of complex regional pain syndrome, and pulmonary embolism.[3,8-11,25] In the current study, 1 patient fell because of weakness due to an insensate lower extremity after perineural catheter activation, and in another patient, the catheters were removed after 6 days because of perifocal soft tissue inflammation.

In the current study, overall mean flexion improved from 74° before treatment to 109° at discharge. Overall mean extension lag decreased from 5.4° to 0.4° at discharge. In the TKA group, mean flexion improved from 76° to 106°, and overall extension lag decreased from 8° to 1°. This is a mean improvement in total ROM of 37° for patients undergoing TKA. These results are comparable with those in previous studies using MUA for knee stiffness after TKA. The reported mean gain in ROM is 20° to 47°.[3,4,7,26,27] Several studies of MUA reported a substantial decrease in ROM over time, which could be explained by a lack of physiotherapy or an abnormal inflammatory response caused by the manipulation.[3,19,28] Forceful manipulation can instantly tear the adhesions and fibrous bands, which results in an immediate gain in ROM. However, it may also cause massive inflammation, which decreases ROM over time.[7] This effect was not observed in the current study population. The authors witnessed small gains of ROM each day of treatment instead of the one large improvement typically seen with MUA.

Namba and Inacio[29] demonstrated that, typically, flexion contractures are not significantly improved after MUA. Knee flexion contractures may place disproportionate strain on the quadriceps muscle and patellofemoral joint, severely impairing function. Thus, a significant increase in extension may have a substantial effect on gait and may contribute significantly to improved function.[5,7] The current study population displayed an improvement in extension lag, with the results persisting to final follow-up.

A paucity of information is available in the literature concerning the revision rate after knee MUA. Tjoumakaris et al[30] studied arthroscopic lysis of adhesions for stiff TKA after failed MUA. They reported that 39 (21%) of 186 patients required an arthroscopic procedure to lyse the adhesions after MUA. Choi et al[31] reported that 15 (12.3%) of 82 patients underwent revision MUA after primary TKA because of remaining stiffness. The revision rate for persistent knee stiffness after manipulation under perineural nerve catheters in the current patient cohort was 15.7%, which is in accordance with the current literature after knee MUA.

A limitation of the current study is the lack of randomization, which might have allowed for undetected bias. In addition, several observers measured ROM and used a standard goniometer for the measurements in daily clinical practice, which may limit the accuracy of the collected data, despite the fact that all observers are experienced in the measurement procedure. Thus, reliability studies have shown that on repeated measures, the standard goniometer demonstrates good overall intratester and intertester reliability.[32] Moreover, patient satisfaction with the outcome was not recorded during the course of the study. The in-hospital protocol might seem excessive in countries used to working with ambulant patients in the postoperative period.

However, in other hospitals, patient discharge with an insensate lower extremity is not allowed. A survey by Klein et al[33] including 2382 peripheral nerve blocks demonstrated that discharge with an insensate upper extremity was prevalent but discharge with an insensate lower limb was uncommon and remains controversial due to the feared complications of stumbling and falling. This fear is based on clinical trials on healthy volunteers, where nerve blocks have been shown to impair proprioception, with joint stiffness possibly being responsible for falls.[34,35] In addition, several case reports and reviews in the literature describe the risks of an insensate lower extremity in the ambulant setting.[36,37] Recent cost analysis studies show that ambulant perineural catheters for the lower extremity in other settings are cost-effective without increasing complications, although a translation to blocks of the proximal lower extremity remains speculative.[38,39]

Finally, the lack of a matched control group precludes direct comparison of the results of the described treatment protocol with other nonoperative interventions for treating knee stiffness.

To the authors' knowledge, this is the first study evaluating the application of perineural catheters of the lower extremity for an in-house physiotherapy program in nonoperative patients and the longer-term effects of this setting on ROM. Additional benefits of this novel approach may be better elucidated in future studies when it is applied to a single surgical procedure. Due to the economic realities in different countries, a prospective, randomized study comparing a perineural catheter–based regimen with a nonoperative intervention in the ambulant setting (using short-acting local anesthetics) is warranted.

References

1. Hegazy AM, Elsoufy MA. Arthroscopic arthrolysis for arthrofibrosis of the knee after total knee replacement. *HSS J.* 2011; 7(2):130-133.
2. Anania A, Abdel MP, Lee YY, Lyman S, Gonzalez Della Valle A. The natural history of a newly developed flexion contracture following primary total knee arthroplasty. *Int Orthop.* 2013; 37(10):1917-1923.
3. Fox JL, Poss R. The role of manipulation following total knee replacement. *J Bone Joint Surg Am.* 1981; 63(3):357-362.
4. Keating EM, Ritter MA, Harty LD, et al. Manipulation after total knee arthroplasty. *J Bone Joint Surg Am.* 2007; 89(2):282-286.
5. Millett PJ, Wickiewicz TL, Warren RF. Motion loss after ligament injuries to the knee: Part I. Causes. *Am J Sports Med.* 2001; 29(5):664-675.
6. Rubinstein RA Jr, DeHaan A. The incidence and results of manipulation after primary total knee arthroplasty. *Knee.* 2010; 17(1):29-32.
7. Witvrouw E, Bellemans J, Victor J. Manipulation under anaesthesia versus low stretch

device in poor range of motion after TKA. *Knee Surg Sports Traumatol Arthrosc.* 2013; 21(12):2751-2758.

8. Insall J, Scott WN, Ranawat CS. The total condylar knee prosthesis: a report of two hundred and twenty cases. *J Bone Joint Surg Am.* 1979; 61(2):173-180.
9. Ivey M. Myositis ossificans of the thigh following manipulation of the knee: a case report. *Clin Orthop Relat Res.* 1985; 198:102-105.
10. Rand JA, Morrey BF, Bryan RS. Patellar tendon rupture after total knee arthroplasty. *Clin Orthop Relat Res.* 1989; 244:233-238.
11. Stecker MS, Ries MD. Fatal pulmonary embolism during manipulation after total knee arthroplasty: a case report. *J Bone Joint Surg Am.* 1996; 78(1):111-113.
12. Ilfeld BM. Continuous peripheral nerve blocks: a review of the published evidence. *Anesth Analg.* 2011; 113(4):904-925.
13. Ilfeld BM. Continuous peripheral nerve blocks in the hospital and at home. *Anesthesiol Clin.* 2011; 29(2):193-211.
14. Malhotra N, Madison SJ, Ward SR, Mariano ER, Loland VJ, Ilfeld BM. Continuous interscalene nerve block following adhesive capsulitis manipulation. *Reg Anesth Pain Med.* 2013; 38(2):171-172.
15. Guardini R, Waldron BA, Wallace WA. Sciatic nerve block: a new lateral approach. *Acta Anaesthesiol Scand.* 1985; 29(5):515-519.
16. Paul JE, Arya A, Hurlburt L, et al. Femoral nerve block improves analgesia outcomes after total knee arthroplasty: a meta-analysis of randomized controlled trials. *Anesthesiology.* 2010; 113(5):1144-1162.
17. Aguirre J, Del Moral A, Cobo I, Borgeat A, Blumenthal S. The role of continuous peripheral nerve blocks. *Anesthesiol Res Pract.* 2012; 2012:560879.
18. Kim J, Nelson CL, Lotke PA. Stiffness after total knee arthroplasty: prevalence of the complication and outcomes of revision. *J Bone Joint Surg Am.* 2004; 86(7):1479-1484.
19. Yercan HS, Sugun TS, Bussiere C, Ait Si Selmi T, Davies A, Neyret P. Stiffness after total knee arthroplasty: prevalence, management and outcomes. *Knee.* 2006; 13(2):111-117.
20. Jackson DW, Schaefer RK. Cyclops syndrome: loss of extension following intra-articular anterior cruciate ligament reconstruction. *Arthroscopy.* 1990; 6(3):171-178.
21. Shapiro MS, Freedman EL. Allograft reconstruction of the anterior and posterior cruciate ligaments after traumatic knee dislocation. *Am J Sports Med.* 1995; 23(5):580-587.
22. Shelbourne KD, Patel DV, Martini DJ. Classification and management of arthrofibrosis of the knee after anterior cruciate ligament reconstruction. *Am J Sports Med.* 1996; 24(6):857-862.
23. Sisto DJ, Warren RF. Complete knee dislocation: a follow-up study of operative treatment. *Clin Orthop Relat Res.* 1985; 198:94-101.
24. Bonutti PM, McGrath MS, Ulrich SD, McKenzie SA, Seyler TM, Mont MA. Static progressive stretch for the treatment of knee stiffness. *Knee.* 2008; 15(4):272-276.
25. Jerosch J, Aldawoudy AM. Arthroscopic treatment of patients with moderate arthrofibrosis after total knee replacement. *Knee Surg Sports Traumatol Arthrosc.* 2007; 15(1):71-77.
26. Daluga D, Lombardi AV Jr, Mallory TH, Vaughn BK. Knee manipulation following total knee arthroplasty: analysis of prognostic variables. *J Arthroplasty.* 1991; 6(2):119-128.
27. Esler CN, Lock K, Harper WM, Gregg PJ. Manipulation of total knee replacements: is the flexion gained retained? *J Bone Joint Surg Br.* 1999; 81(1):27-29.
28. Ipach I, Schafer R, Lahrmann J, Kluba T. Stiffness after knee arthrotomy: evaluation of prevalence and results after manipulation under anaesthesia. *Orthop Traumatol Surg Res.* 2011; 97(3):292-296.
29. Namba RS, Inacio M. Early and late manipulation improve flexion after total knee arthroplasty. *J Arthroplasty.* 2007; 22(6)(suppl 2):58-61.
30. Tjoumakaris FP, Tucker BC, Post Z, Pepe MD, Orozco F, Ong AC. Arthroscopic lysis of adhesions for the stiff total knee: results after failed manipulation. *Orthopedics.* 2014; 37(5):e482-e487.
31. Choi HR, Siliski JM, Malchau H, Kwon YM. Effect of repeated manipulation on range of motion in patients with stiff total knee arthroplasty. *Orthopedics.* 2015; 38(3):e157-e162.
32. Brosseau L, Balmer S, Tousignant M, et al. Intra- and intertester reliability and criterion validity of the parallelogram and universal goniometers for measuring maximum active knee flexion and extension of patients with knee restrictions. *Arch Phys Med Rehabil.* 2001; 82(3):396-402.
33. Klein SM, Nielsen KC, Greengrass RA, Warner DS, Martin A, Steele SM. Ambulatory discharge after long-acting peripheral nerve blockade: 2382 blocks with ropivacaine. *Anesth Analg.* 2002; 94(1):65-70.
34. Muraskin SI, Conrad B, Zheng N, Morey TE, Enneking FK. Falls associated with lower-extremity-nerve blocks: a pilot investigation of mechanisms. *Reg Anesth Pain Med.* 2007; 32(1):67-72.
35. Bortolami SB, DiZio P, Rabin E, Lackner JR. Analysis of human postural responses to recoverable falls. *Exp Brain Res.* 2003; 151(3):387-404.
36. Ilfeld BM, Duke KB, Donohue MC. The association between lower extremity continuous peripheral nerve blocks and patient falls after knee and hip arthroplasty. *Anesth Analg.* 2010; 111(6):1552-1554.
37. Saporito A, Sturini E, Petri J, Borgeat A, Aguirre JA. Case report: unusual complication during outpatient continuous regional popliteal analgesia. *Can J Anaesth.* 2012; 59(10):958-962.
38. Saporito A, Calciolari S, Ortiz LG, Anselmi L, Borgeat A, Aguirre J. A cost analysis of orthopedic foot surgery: can outpatient continuous regional analgesia provide the same standard of care for postoperative pain control at home without shifting costs? *Eur J Health Econ.* Epub ahead of print.
39. Saporito A, Sturini E, Borgeat A, Aguirre J. The effect of continuous popliteal sciatic nerve block on unplanned postoperative visits and readmissions after foot surgery: a randomised, controlled study comparing day-care and inpatient management. *Anaesthesia.* 2014; 69(11):1197-1205.